Strong-strong Beam-beam simulation for Muon collider

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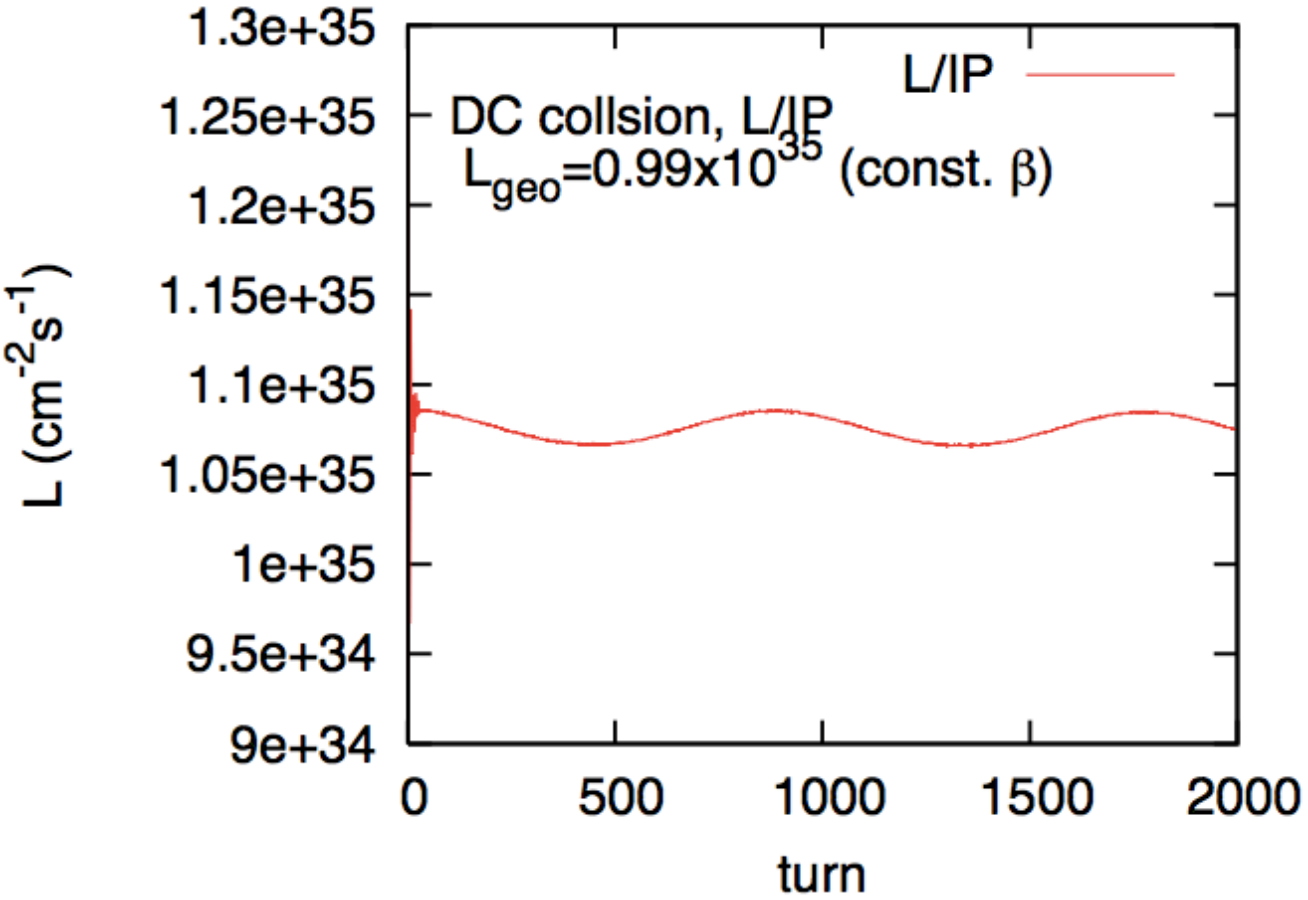
Parameters by Y. Alexahin

Table 1: Baseline muon collider parameters [2].

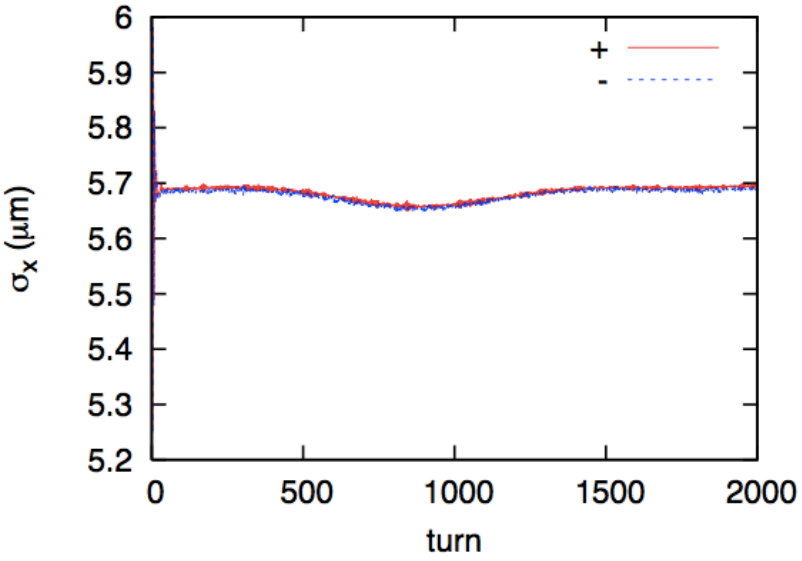
Parameter	*Unit*	*Value*
Beam energy	TeV	0.75
Repetition rate	Hz	15
Average luminosity / IP	$10^{34}/cm^2/s$	1.1
Number of IPs, N_{IP}	-	2
Circumference, C	km	2.73
β^*	cm	1 (0.5-2)
Momentum compaction, α_p	10^{-5}	-1.3
Normalized emittance, $\varepsilon_{\perp N}$	π·mm·mrad	25
Momentum spread	%	0.1
Bunch length, σ_s	cm	1
Number of muons / bunch	10^{12}	2
Beam-beam parameter / IP, ξ	-	0.09
RF voltage at 800 MHz	MV	16
Betatron tunes	-	20.56 / 16.58
Synchrotron tune	-	0.00057

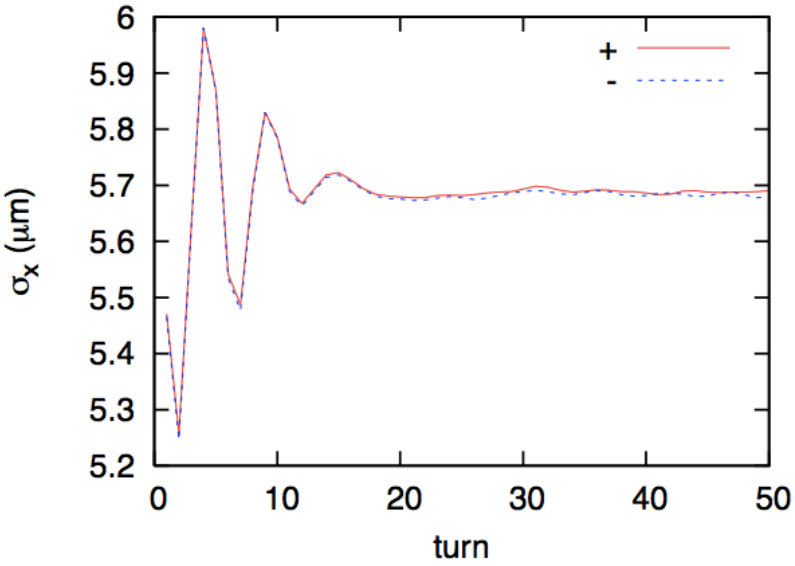
Simulation for 1 IP

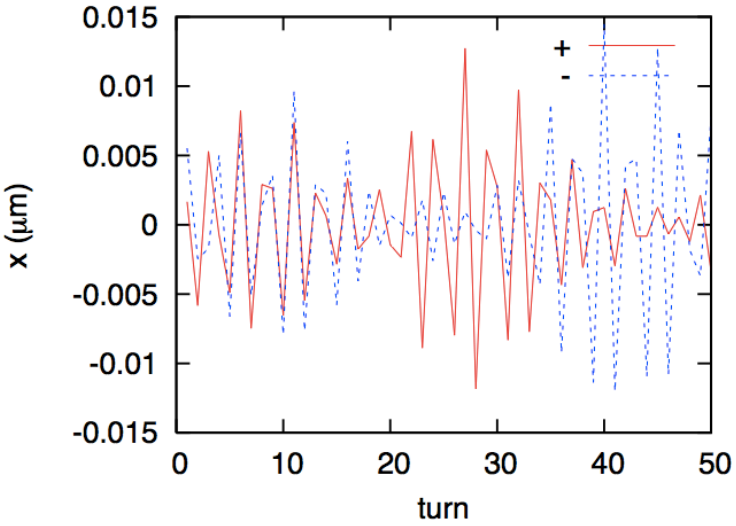


ν_x, ν_y=0.56,0.58

Beam amps. and sizes in the simulation

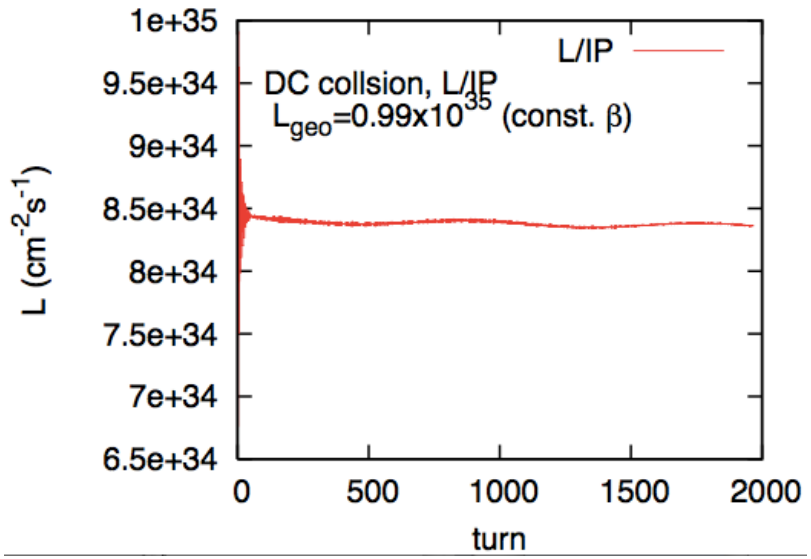


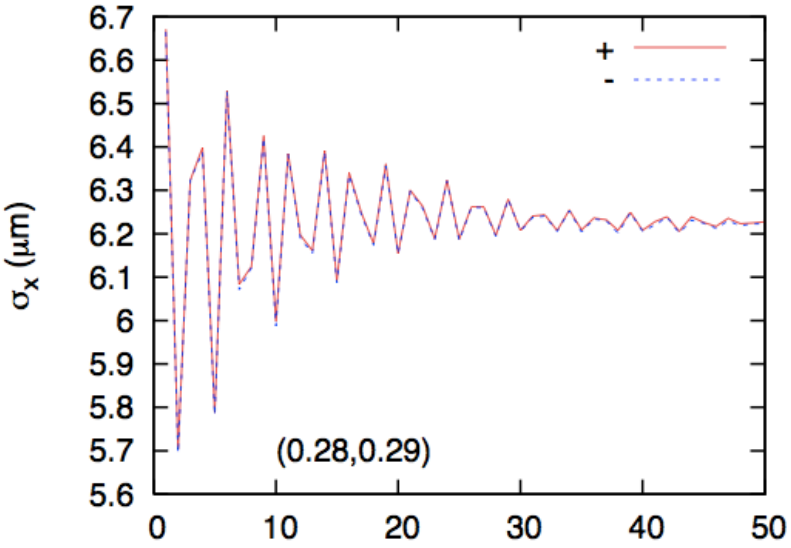




- Mismatch in the first 20 turns is seen.
- Amplitude is 0.1%σx, where the number of macro-particles is 2×10^6.

ν_x, ν_y=0.28,0.29





- Dynamic effect still remains in α.
- The beam is initialized just before collision.
- The beam size is plotted just before collision.

Mismatch correction

- 0.56,0.58

$$Bx = \begin{pmatrix} 3.240\times10^{-11} & 3.756\times10^{-10} \\ 3.756\times10^{-10} & 4.942\times10^{-7} \end{pmatrix}; \qquad By = \begin{pmatrix} 3.160\times10^{-11} & 3.798\times10^{-10} \\ 3.798\times10^{-10} & 4.489\times10^{-7} \end{pmatrix};$$

$\beta x=0.00813 \quad \alpha x=-0.0943 \quad \varepsilon x=3.98\times10^{-9}$

$\beta y=0.00843 \quad \alpha y=-0.101 \quad \varepsilon y=3.75\times10^{-9}$

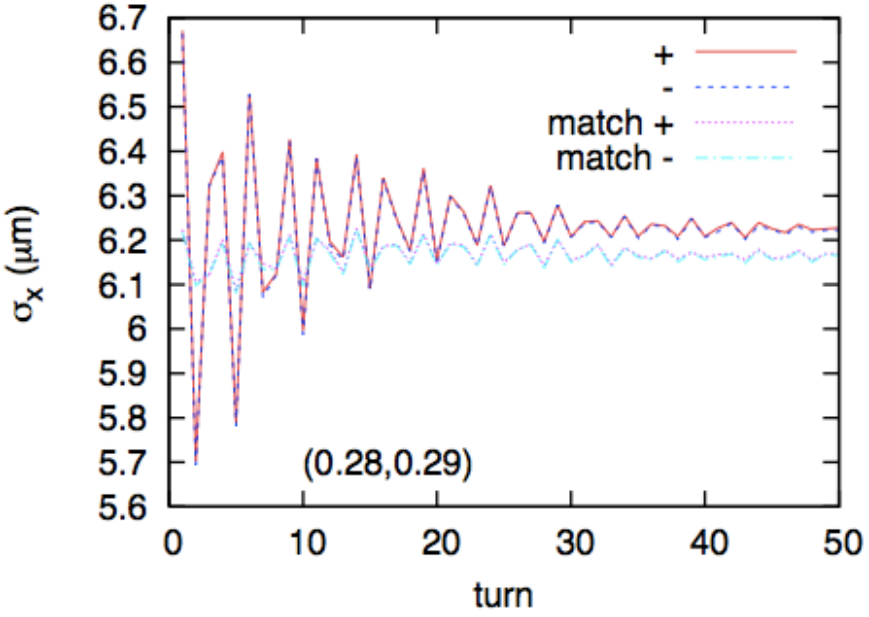
- 0.28,0.29

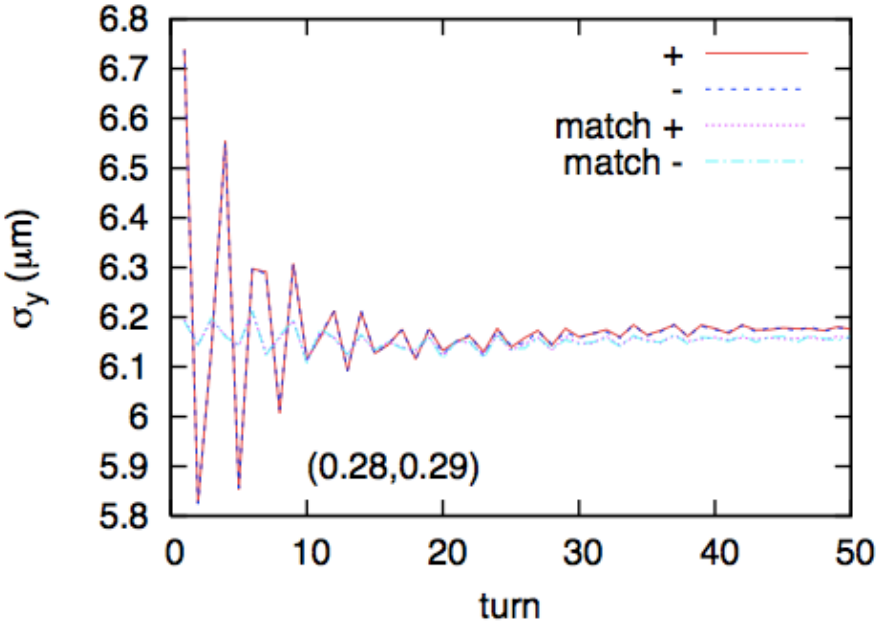
$$Bx = \begin{pmatrix} 3.897\times10^{-11} & 5.067\times10^{-10} \\ 5.067\times10^{-10} & 3.686\times10^{-7} \end{pmatrix}; \qquad By = \begin{pmatrix} 3.828\times10^{-11} & 5.216\times10^{-10} \\ 5.216\times10^{-10} & 3.352\times10^{-7} \end{pmatrix};$$

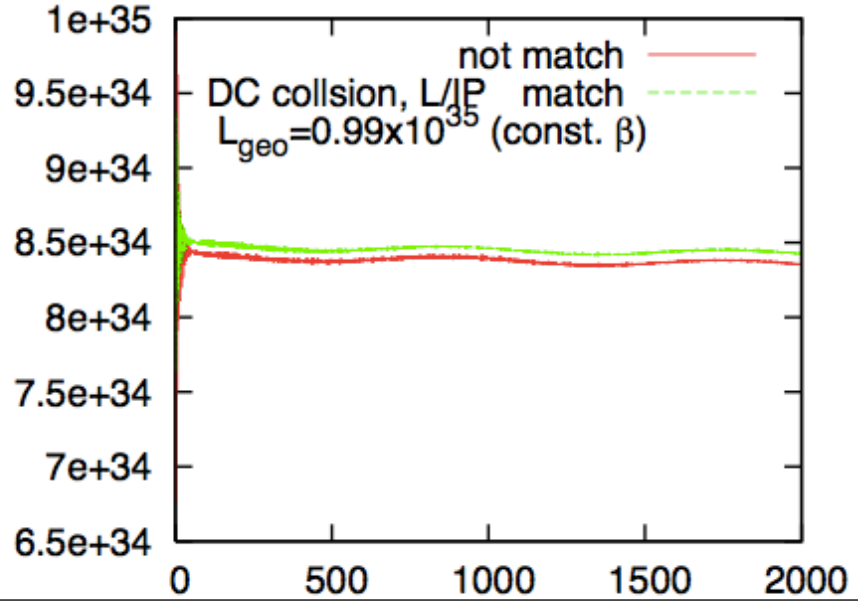
$\beta x=0.0104 \quad \alpha x=-0.135 \quad \varepsilon x=3.76\times10^{-9}$

$\beta y=0.0108 \quad \alpha y=-0.147 \quad \varepsilon y=3.54\times10^{-9}$

After matching

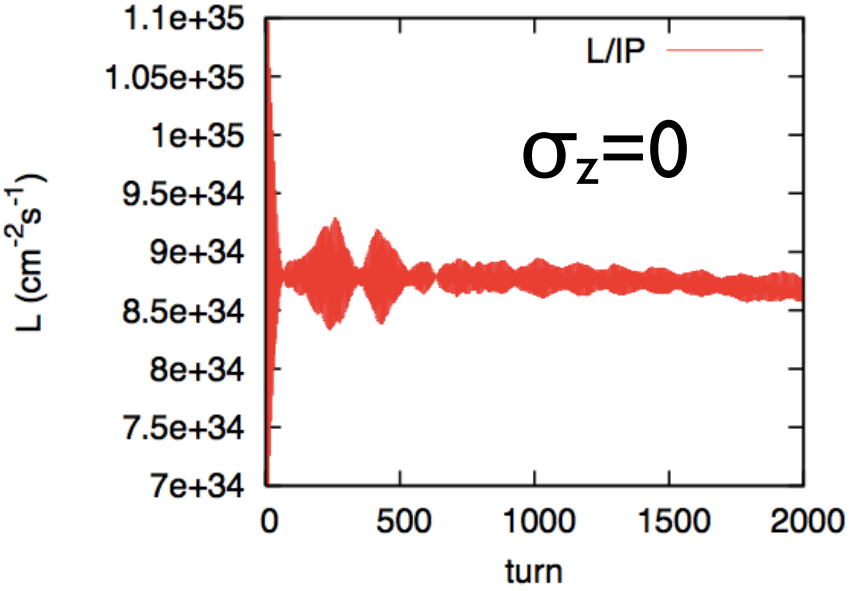


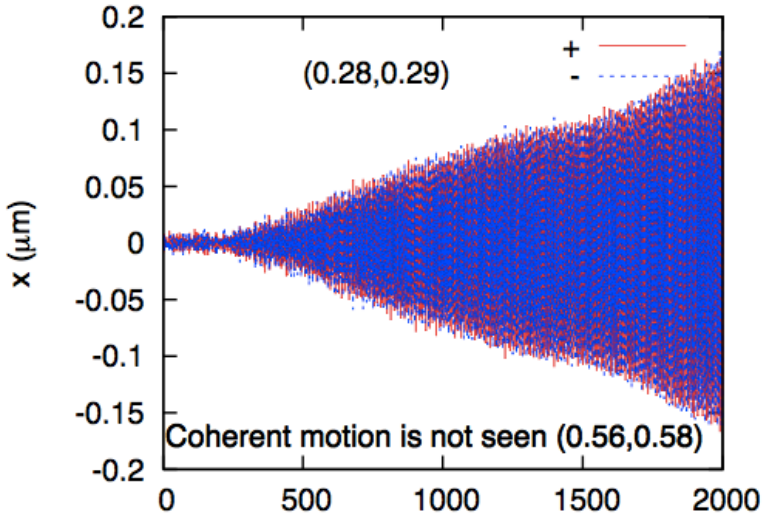


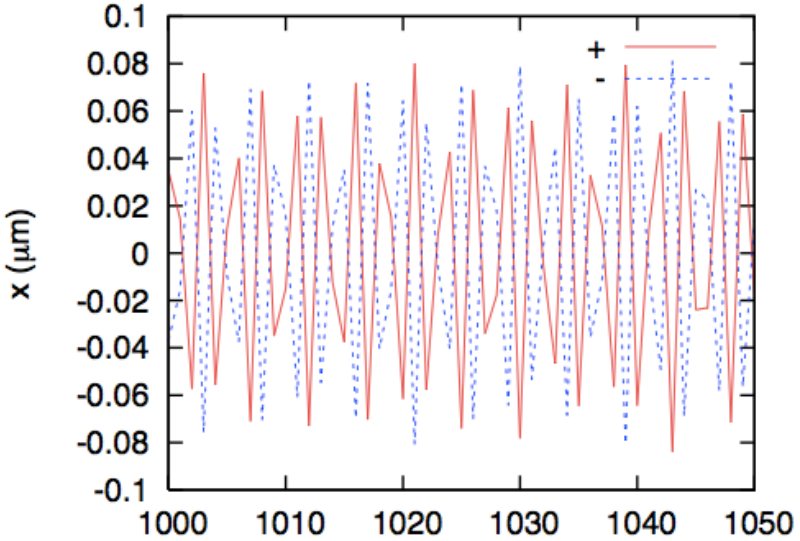


- Beam size is matched better.
- Emittance is larger ~7%. at the early stage.

Coherent motion seen in 2D model

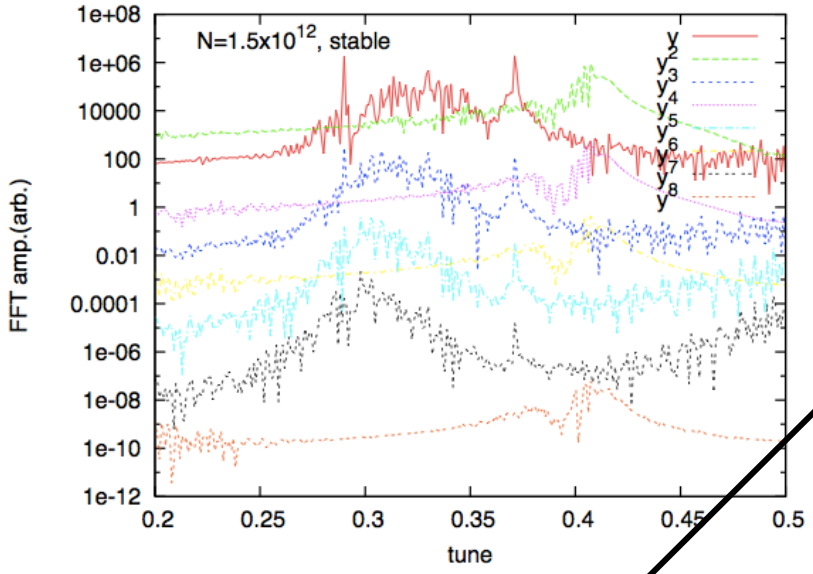




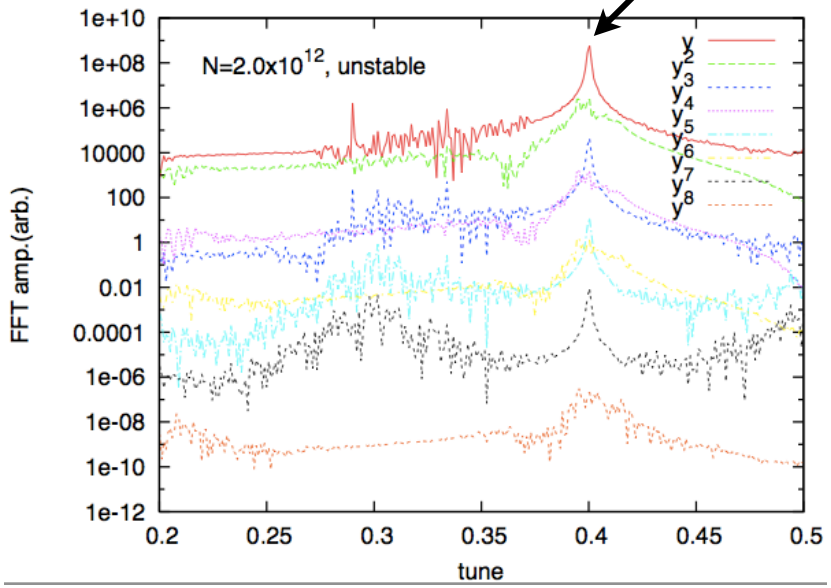


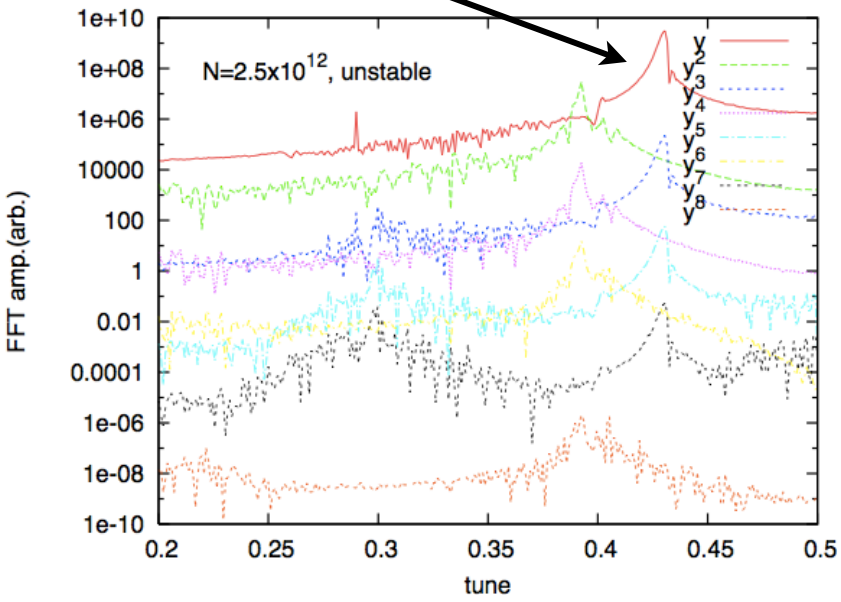
- Some luminosity degradation is seen.
- Coherent motion (π mode appears.
- The coherent motion does not appear at (0.56,0.58).
- It does not appear 3D simulation.

FFT of y^n

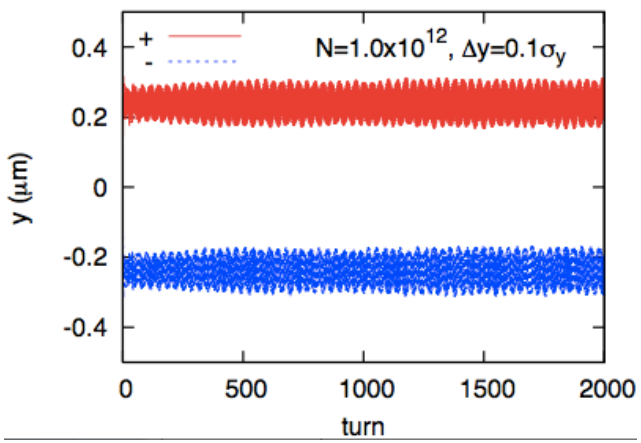


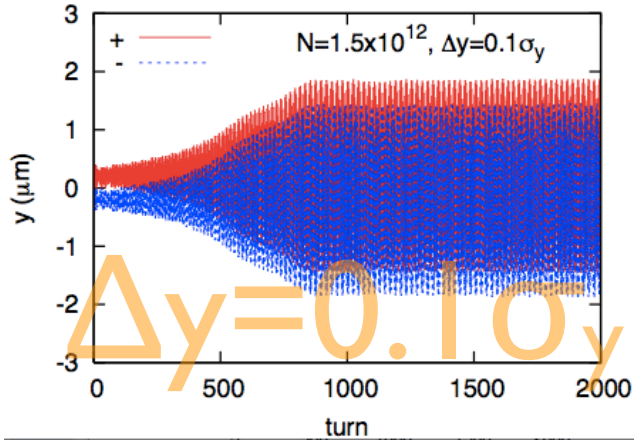
- Mode coupling of π and $2\nu_y$.
- Modes are separated.

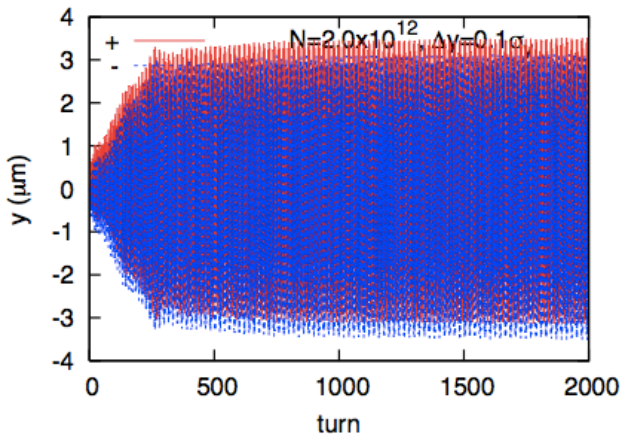




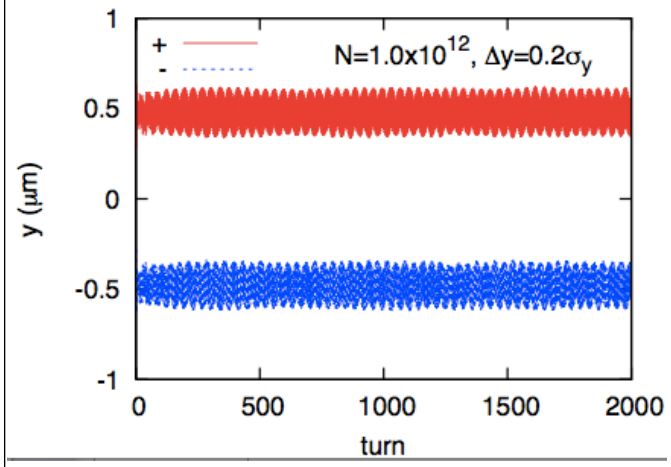
Collision with an offset (2D)

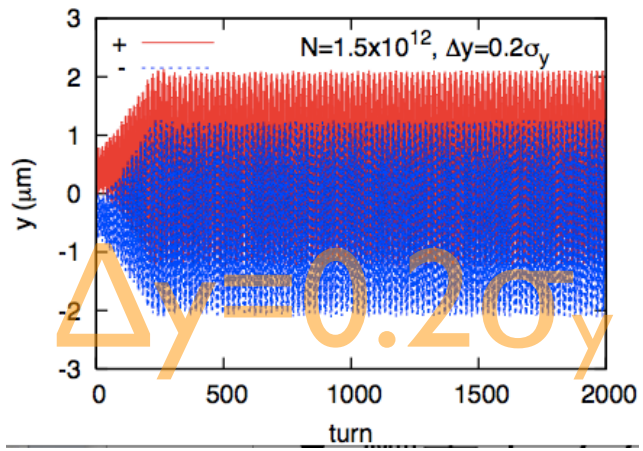


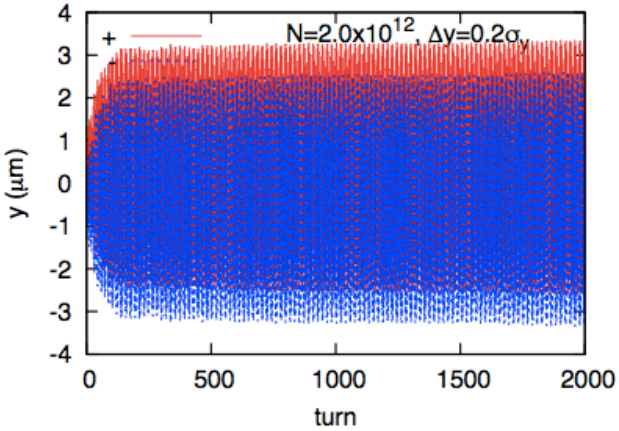




- N_μ=1x10^10 1.5x10^10 2x10^10



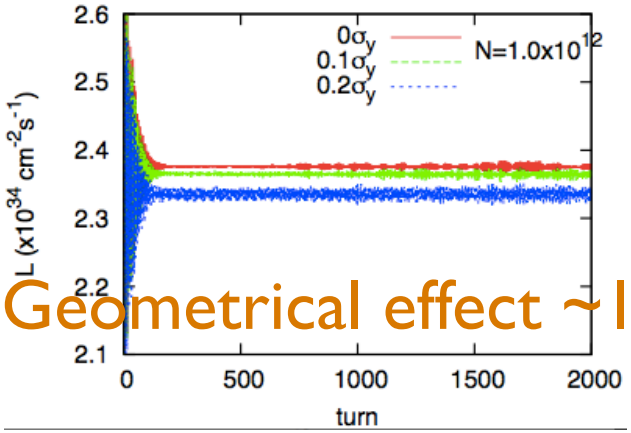




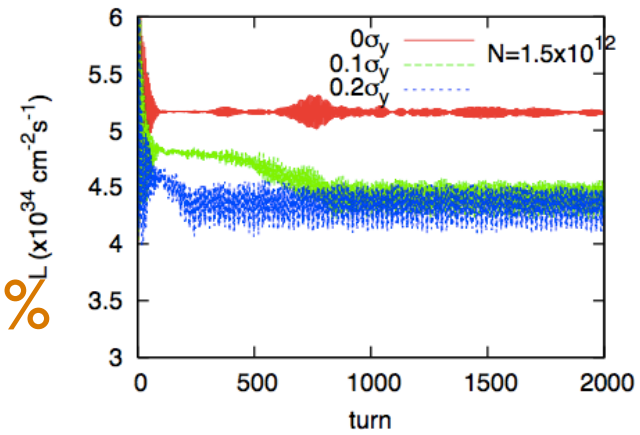
Collision with an offset (2D)

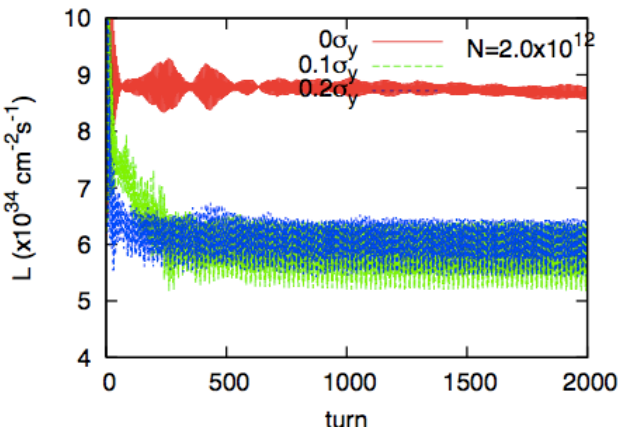
- Luminosity

N_μ=1x10^{10} 1.5x10^{10} 2x10^{10}

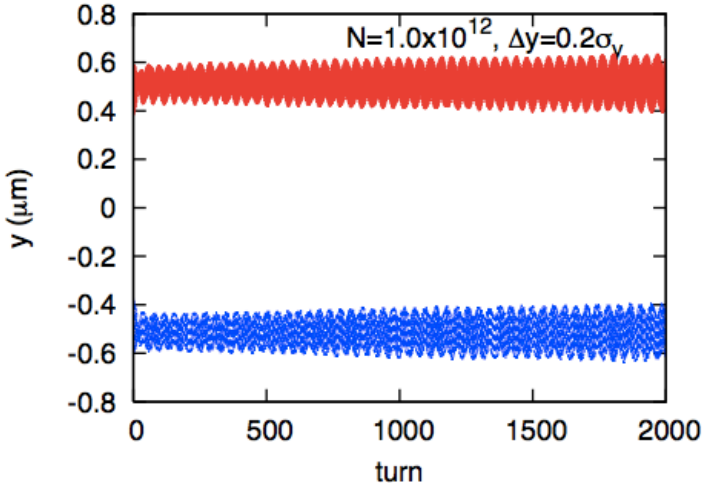


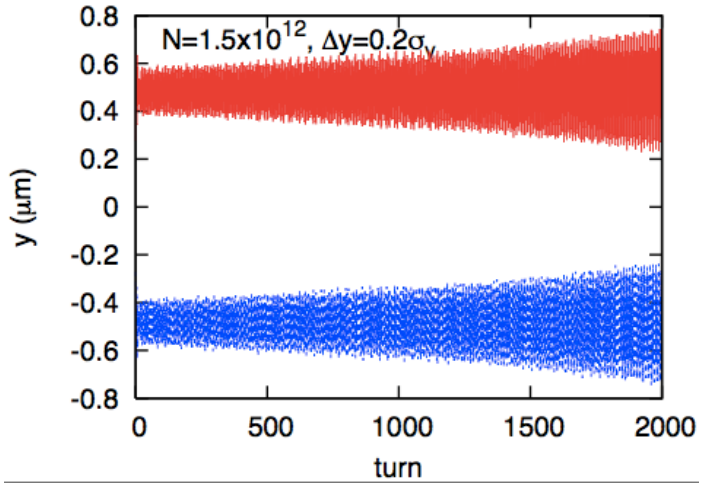
Geometrical effect ~1%

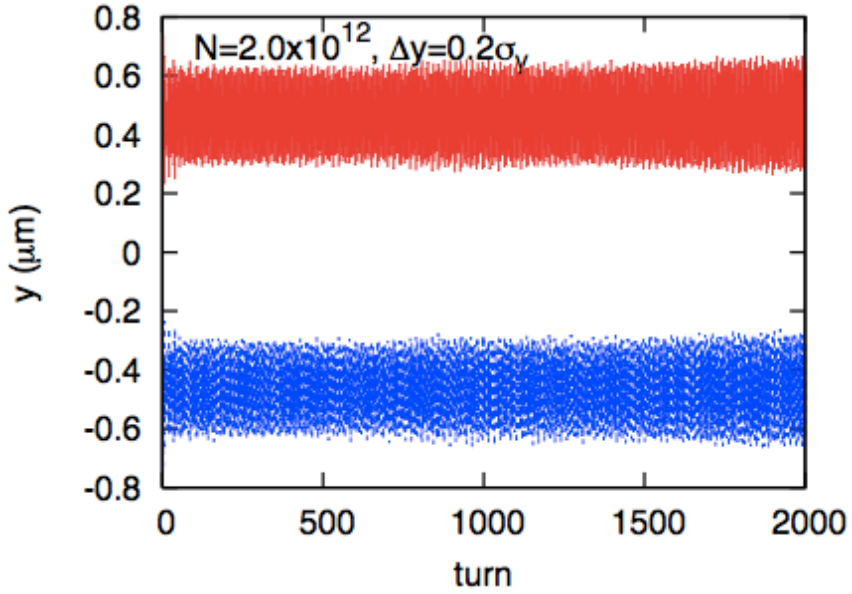


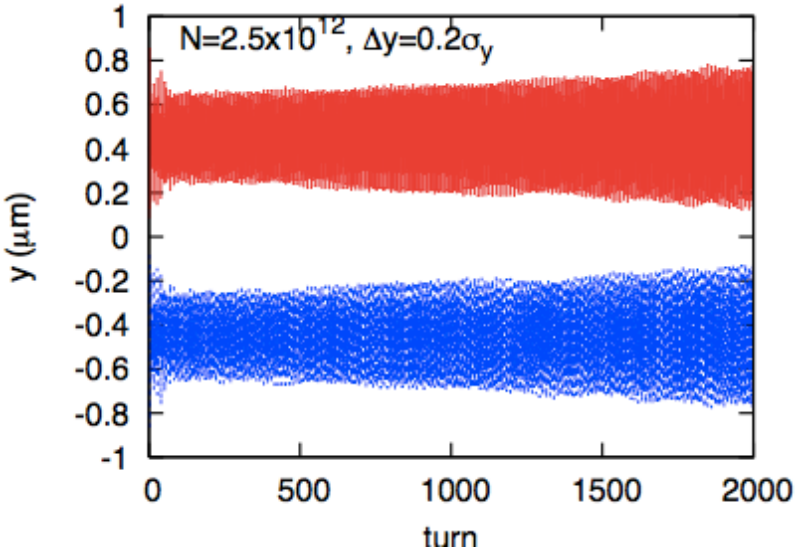


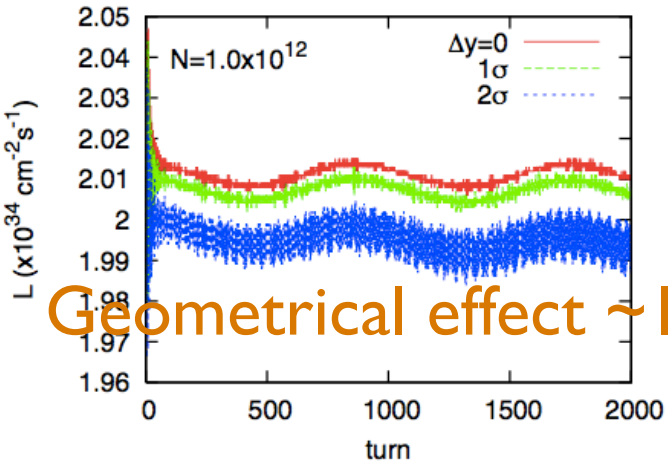
Collision with an offset (3D)

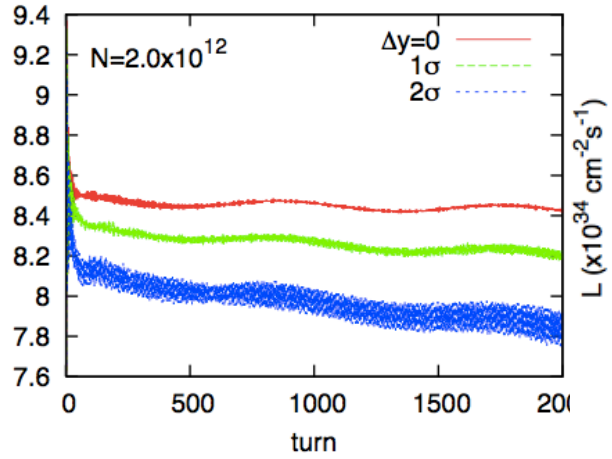


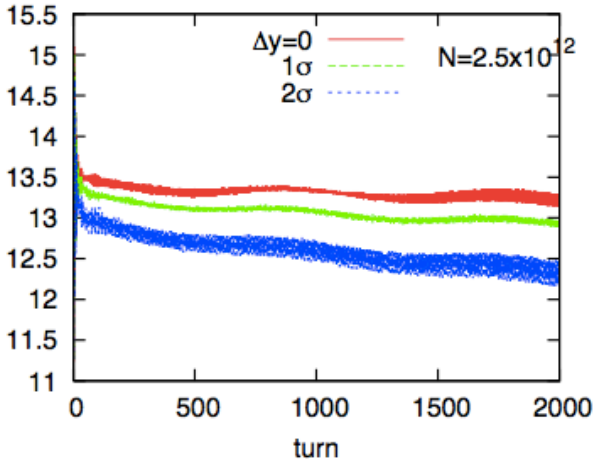












Geometrical effect ~1%

Wake field

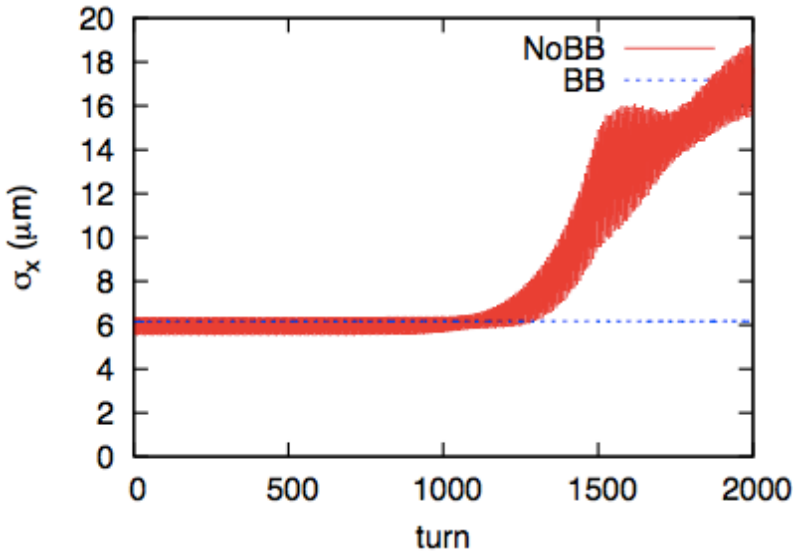
$$\Upsilon = \frac{N_\mu r_\mu W_0 L}{8\pi\nu_\beta\gamma}$$

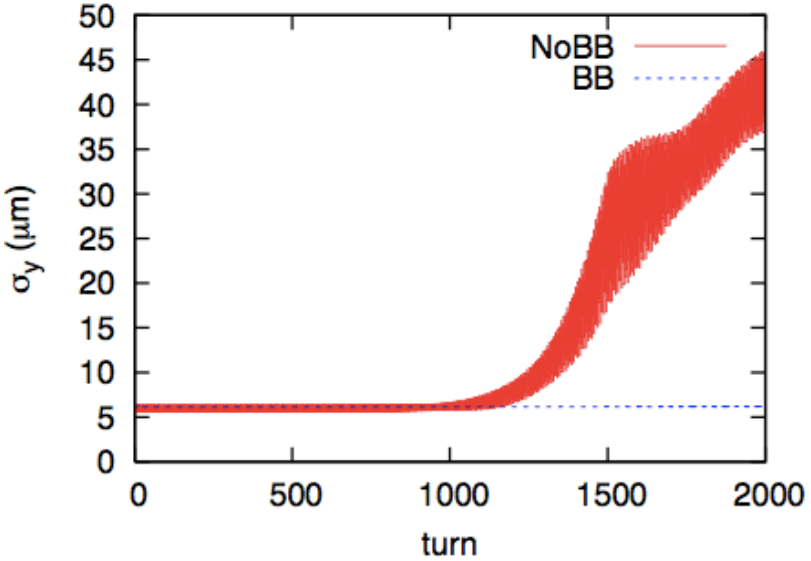
$$\Upsilon = 0.01$$

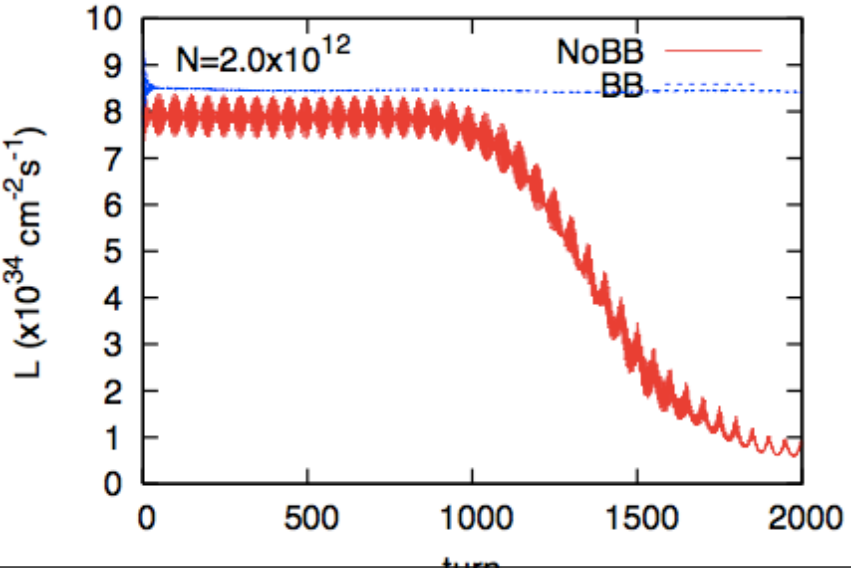
$$W_0 = 4.93 \times 10^5 \ \mathrm{m}^{-2}$$

- Input Wake in the code (σz=0.01m, k=100)

$$W_\perp = 2W_0 \sin(kz)$$


NoBB
BB
σx (μm)
turn
0
2
4
6
8
10
12
14
16
18
20
0
500
1000
1500
2000


NoBB
BB
σy (μm)
turn
0
5
10
15
20
25
30
35
40
45
50
0
500
1000
1500
2000


N=2.0x10^12
NoBB
BB
L (x10^34 cm^-2s^-1)
turn
0
1
2
3
4
5
6
7
8
9
10
0
500
1000
1500
2000